Washington State Department of Health

Indoor Air Quality Primer
An Overview of Residential Indoor Air Problems

The purpose of this document is to give the reader a brief overview of possible residential indoor air quality (IAQ) problems and provide a basic understanding of problem identification, control methodologies, some specific pollutants, their sources, potential health effects, and indoor air monitoring methodology.

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Background

IAQ in our homes, schools, and office buildings has received increasing attention in the past few years from scientists, engineers, regulatory groups, and the public. There is growing concern and mounting evidence that our indoor environment may be responsible for persistent, irritating health effects. Traditionally, it has been assumed that people were protected from air pollution when indoors, particularly near industrialized areas. However, recent research has shown that this is not necessarily true. Current research indicates that our indoor air may be more polluted than outside air, even in industrialized areas. This increased concern is accompanied by the realization that most people spend 80-90 percent of their time indoors and that the young, aged, and health-compromised may be at greater risk.

As a result of the energy crisis of the early seventies, the cost of energy increased by a factor of almost ten. During that time, the U.S. Government, private industry, and the commercial

sector all developed ways to better design new buildings and homes, as well as retrofit existing buildings and homes with better insulation and energy conservation devices. This resulted in energy savings by decreasing ventilation, thus reducing or eliminating the amount of outside air that needs to be heated or conditioned. However, the efforts to conserve energy, along with the increasing use of synthetic building materials, contributes to an indoor air environment that is a possible cause of increasing adverse health effects. In certain circumstances, reduced ventilation alone has resulted in adverse health effects to occupants due to increased levels of indoor air pollutants.

Several indoor air pollutants have received special public health attention. These include formaldehyde, asbestos, radon, and tobacco smoke. Other indoor pollutants that can be associated with health or irritating effects are carbon monoxide, nitrogen oxides, household and personal care products, microorganisms, and allergens.

Although standards for work place exposure to many toxic compounds have been established in the United States and other countries, almost no regulatory standards or guidelines have been established in the U.S. for residential indoor air. Several other countries have established residential IAQ standards for several pollutants, particularly formaldehyde. Our ability to accurately assess the health risks associated with exposure to these compounds is limited. There is insufficient data on the number of people exposed, the susceptibility of individuals, the patterns and degree of exposure, and the actual health effects from exposure to low levels and mixtures of pollutants typically found in the residential environment.

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Problem Identification

IAQ related illnesses are usually characterized by one or more of the following symptoms: irritation of the eyes, nose and/or throat; headache; cough; runny nose; lethargy; and difficulty sleeping. Other less common symptoms reported include dizziness, nausea, diarrhea, dry skin, and rash. Symptoms appear unrelated to any identifiable common illness. However, because these symptoms are common to many different ailments, a physician, allergist, or dermatologist should be consulted to determine any physical condition that may account for the symptoms experienced. The symptoms are often most severe during the winter months. Symptoms may affect only selected individuals in the home and usually are most severe in family members who spend the greatest amount of time at home, such as mothers and their young children. Symptoms become less severe when away from the indoor environment in question and often disappear with extended absences (e.g., during vacations). Symptoms will often become less severe or disappear when the home is ventilated by opening windows or during cold winter days when air infiltration is high and humidity is low.

The first appearance of symptoms is commonly associated with:

- Moving into a recently purchased home or new mobile home.
  - Recent remodeling.
  - Homes with urea-formaldehyde foam insulation.

- Implementing energy conservation measures that significantly reduce heat loss and ventilation rates.
  - Purchase of new furnishings.
  - Installation of new kitchen or bathroom cabinets.
  - Installation of new carpeting or cleaning of carpeting.
  - Use of some recreational vehicles.

Office building workers have often been victims of indoor air pollution commonly referred to as "Sick Building Syndrome" (SBS). SBS events are characterized by a significant number of building occupants with specific health complaints. Investigations usually reveal several indoor pollutants, more often than not in extremely low concentrations. Usually no one indoor air pollutant can be identified as the likely cause of health complaints. It is often thought that the many pollutants in combination are responsible for reported health effects. Investigations have indicated that SBS occurs most often in buildings where ventilation rates are maintained near minimum requirements. Often improved ventilation alleviates the problem. Nonresidential IAQ is discussed in a separate fact sheet distributed by the Washington State Department of Labor and Industries. Copies can be obtained by calling 360-902-5436.

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Control of Indoor Air Pollutants

Three general methods are used for controlling indoor air pollutants: source removal or modification, ventilation, and air cleaning.

Source Removal/Source Modification

Source removal and source modification (or substitution) are generally considered before other alternatives because the pollutant sources and their rates of emission are the most important factors in determining the overall IAQ. Source removal is the most desirable since it permanently removes the pollutant source. In practice, source modification and substitution are the more common forms of control. Source modification involves measures to reduce pollutant emissions, such as restricting smoking. Substitution usually involves replacement with a less toxic alternative, such as water based products versus solvent based.

Dilution Ventilation

Ventilation can be used to reduce pollutant concentrations to levels below which no adverse health effects are experienced. By increasing the ventilation rate in a building, pollutants are rapidly dissipated by providing less contaminated air from the outside to mix with and dilute higher indoor contaminant levels. This is generally accomplished through non-mechanical means such as infiltration or by opening windows and doors.

In older homes and new homes that are not well sealed, the air exchange rate is usually between 0.8 and 1.5 air changes per hour (ACH). Newer, well-constructed houses and older, weatherized houses generally have between .5 and 1.0 ACH. Apartments often have even lower ACH. One researcher reports that each 30 percent reduction in the ventilation rate, as can be expected between energy efficient and non-energy efficient

homes, results in a 43 percent increase in indoor air contaminants. This increase is also dependent upon the contaminant, its source strength, and rate of emission.

For homes with very low ACH and those with certain pollutant producing sources, an active mechanical ventilation system may be necessary. This may be either a system for the entire home or to control a specific pollutant produced from an activity or appliance. or instance, it is recommended that gas ranges have a mechanical exhaust hood located directly above the cooking surface to exhaust combustion by-products directly to the outside. Because of the additional heating or cooling costs associated with whole house ventilation systems, such ventilation is not recommended without heat recovery. An efficient, economical mechanical ventilation system for the entire home is an air-to-air heat exchanger. These systems, when properly sized and installed, can provide an average of 60-85 percent heat recovery from exhaust air and substantially reduce the energy penalty associated with forced ventilation. In general, the higher the forced ventilation rate the greater the reduction in pollutants.

While ventilation is frequently helpful in reducing indoor air contaminant concentrations, it is more efficient to reduce or eliminate pollutants at the source.

Air Cleaning

Air cleaners operate by mechanical filtration, absorption, adsorption, or electrostatic precipitation of pollutants. Extended surface pleated filters serve the most effectively and will be the most useful over the widest range of pollutant types. These filters are available as stand-alone units, as add-ons, or as in-lines for most home systems. Filter size and efficiency vary. Contact your home system contractor for specific applications.

Negative ion generators can be effective air cleaners. Negative ion generators emit negative charged ions which attach to airborne particles, which then attach themselves to room surfaces removing them from the air. These particles, however, are potentially subject to resuspension and should be removed with high efficiency particulate air vacuum cleaners. Although some advertisers' claims regarding effectiveness and health benefits have not been verified, this method is considered moderately effective at reducing particulate levels.

Electrostatic air precipitators are an effective air cleaning method to reduce indoor particulates. These units operate by putting an electrical charge on particulates and then removing them from the air by attracting them to an oppositely charged plate. These units are available for installation in the duct of a forced air heating or ventilation system or as independent units. Electrostatic precipitators and negative ion generators may produce ozone, a potential respiratory irritant. However, the amount of ozone produced is usually quite small.

Activated carbon and specialty filters with adsorbents are available for the removal of gaseous contaminants. This method of filtration can be quite effective; however, sizing and maintaining this type of filtration system can be complicated. The Department of Health recommends that you contact your heating contractor for help in selecting this type of filtration system.

Ozone generating devices have been much touted as the final cure for all indoor air problems. Testing has been done which indicates that these devices can and do exceed the work place standard of 0.1 parts per million (PPM). Since ozone is a potent irritant and toxic material implicated in lung tissue changes, immune system dysfunction and asthma severity and attack rates the Department of Health recommends against the use of ozone generating devices in an occupied space.

Additional information on filter types and applications can be obtained at the Environmental Protection Agency (EPA) IAQ clearinghouse at 1-800-438-4318, or through the American Lung Association at 1-800-LUNG USA.

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Pollutants

The following is a brief discussion of common indoor air pollutants, their sources, potential health effects and acceptable mitigation measures. Pollutants included in this discussion are:

Asbestos

Asbestos is the generic name for several fibrous minerals. The three main types are chrysotile (white), crocidolite (blue), and amosite (brown). Asbestos' characteristics of flexibility, strength, incombustibility, and durability resulted in its widespread use between the 1920s and mid 1970s. Chrysotile asbestos accounts for approximately 95 percent of all asbestos used and is anticipated to be less pathogenic than the amphibole type asbestos products.

Sources

Asbestos-containing materials may be present in many household products manufactured before 1977, as well as in many areas in and around the home. Some of the more common locations are old pipe and furnace insulation, vinyl floor tiles and vinyl sheet flooring, patching compounds and textured paints, brake and clutch pads, roofing materials, home siding, some 1930-1950 wall and ceiling insulations,

some decorative ceiling materials, and other items requiring the characteristics of asbestos.

Health Effects

Asbestos exposure has been shown to cause cancer of the lung; a rare cancer of the chest and abdominal lining called mesothelioma; and cancers of the esophagus, stomach, colon, and other organs. It can also cause a noncancerous chronic and debilitating lung disease called asbestosis. Asbestosis is related to lengthy exposure to high levels of asbestos fibers as was common in some industrial environments during the 1920s to the 1940s. Asbestosis is not considered a significant outcome from incidental nonoccupational exposure. The amount of exposure necessary to cause disease is unknown and is probably different for different population subgroups. Asbestos-related diseases generally do not appear for 15-35 years after first exposure. This length of time between first exposure and onset of disease appears to be related to the amount and duration of exposure. However, it is believed that any exposure to asbestos involves some health risk. No safe level of exposure has been established.

Asbestos and cigarette smoking combined significantly increase the potential for lung cancer. Studies have shown asbestos workers who smoke have a risk of lung cancer eight times greater than smokers in the general population. This same group has a lung cancer risk 92 times greater than unexposed nonsmokers.

The presence of asbestos in the home alone does not necessarily mean there is an exposure problem. Asbestos is hazardous if inhaled and this usually occurs only when asbestos-containing materials have been damaged and there is a release of asbestos fibers. Of greatest concern are asbestos products that are friable (this means easily crumbled, pulverized, or powdered by hand). Unless the material is crumbling, needs repair, or must be removed, it is recommended that it not be disturbed. Improper removal and handling can release high levels of fibers into the air that then become a continual source of exposure.

Control Methods

Asbestos control methods generally include source removal or source modification. Small minor repairs can often be taken care of by duct tape or other commercial products which seal the damaged area. Heat resistant paints and sealers are also sometimes suitable for small repairs. These products are often available through commercial paint and safety supply outlets.

Removal should be done only when necessary. Although current law permits a homeowner to perform their own removal work, **it is recommended that removal work be done only by contractors with highly-trained workers** who are required to be certified by the Washington State Department of Labor and Industries. These workers are knowledgeable about the permits that must be obtained, safe removal practices, necessary protective equipment, and proper disposal methods.

Homeowners choosing to do their own removal must first notify their local air pollution control authority. They may also be required to notify their local health

department and other local government agencies. Information regarding proper removal practices, protective equipment, and disposal can be obtained through local health departments, local air pollution control authorities, and the Department of Labor and Industries.

For more information on asbestos, please see these asbestos links

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Combustion By-Products

Indoor combustion of fuels can be a source of increased concentrations of gases and particulates. The major combustion by-products of concern are carbon monoxide (CO), nitrous oxides (NOx), and RSP. Other by-products may include sulfur dioxide, formaldehyde, carbon dioxide, hydrogen cyanide, and organic vapors. Common sources of indoor combustion by-products are unvented kerosene heaters, wood stoves, gas stoves, and tobacco smoke.

Carbon Monoxide

Carbon Monoxide (CO) is a colorless, odorless gas produced through incomplete combustion. CO is a poison that binds with hemoglobin, the oxygen-carrying molecule in human blood. Because CO's affinity to bind with hemoglobin is 250 times greater than oxygen, low airborne concentrations and long exposure times can result in substantial carboxyhemoglobin (COHb) concentrations in the blood. COHb is CO bound to hemoglobin. As COHb levels increase, less hemoglobin is available for the transport of oxygen. This lack of oxygen-carrying capability, which is indicated by the increase in COHb, results in the symptoms we associate with CO poisoning.

Health Impacts

The acute health effects of CO exposure are well established. Mild exposure symptoms may include headache, dizziness, decreased vigilance, decreased hand-eye coordination, weakness, confusion, disorientation, lethargy, chest pain (in cardiac patients), nausea, and visual disturbances. Greater or prolonged exposure can cause unconsciousness and death. The severity of symptoms depends on the concentration of CO, length of exposure, and degree of physical activity, as well as the state of health of the exposed individuals. People who are exposed to high CO concentrations for long periods of time during strenuous activity will reach the highest COHb levels.

Even low levels of CO can present a health risk to susceptible individuals, such as persons with heart disease, sickle cell disease, and anemia. Age and general health may also affect susceptibility to CO. Exposure to low levels of CO may harm the developing fetus.

Angina pectoris is chest pain associated with impaired oxygen flow to the heart and may occur at COHb levels between 2.5 and 4.9 percent in cardiac patients.

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In healthy individuals, decreased vigilance, confusion and disorientation, behavioral, and central nervous system effects occur at COHb levels between 4 and 6 percent. **Remember that as symptoms of CO poisoning increase, you may become confused and less capable of making decisions that could save your life.**

Sources of Environmental Pollution

The National Ambient (outdoor) Air Quality Standard for CO is 9 PPM averaged over an eight hour period, or 35 PPM averaged over one hour. These standards are based on preventing adverse effects in individuals with cardiac or vascular disease and in exercising humans. Seattle, Spokane, Yakima, and parts of Pierce and Thurston counties may exceed these values during heavy traffic periods and when inversions occur. Inversions occur when cold stable air layers form above warmer air. This traps pollutants beneath the stable air layer. This can result in significant pollutant level increases, including CO. As outdoor levels increase due to peak traffic times, or because of an inversion, indoor levels will rise proportionately. If indoor sources of CO exist, indoor levels will be higher than those outside. **Avoid strenuous physical activity during peak traffic times, in high volume traffic areas, and during inversions.**

Appliances

Indoor wood stoves, gas ranges, gas hot water heaters, gas and oil heaters, furnaces, and kerosene space heaters can all be sources of CO. Heating season is a time of particular concern with regard to CO exposure. as and oil heaters that have not been used during the warm summer months should not be expected to perform efficiently without the benefit of service. It is imperative that furnaces be cleaned and serviced following the manufacturers instructions. Winter is also the time of year when people use space heaters. **It is very important to use the correct grade of kerosene (1-K or manufacturers suggested grade). Use of the incorrect grade of fuel will result in an increased production of CO.**

Flame color is a good way to check the combustion of a fuel burning appliance. The flame should burn with a bright blue color. A yellow flame signals poor combustion and may indicate a problem with the flue or burner. Ideally, combustion air for fuel burning appliances should not be drawn from inside the home. Some newer furnaces draw air from outside the home and this alleviates the possibility of back drafting. Fuel burning appliances which do not draw combustion air from outside the home are subject to back drafting, which occurs when flue gases, including CO, are drawn back through the flue into the living space in the home. This occurs because of an air pressure drop in the home resulting from high wind conditions or in tight homes when local exhaust fans are used without adequate make-up air. Back drafting may also be caused by blocked or partially blocked flues. Flues should be inspected regularly. **If you suspect back drafting contact your furnace service representative or your fuel supplier.**

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Power outages are a time of higher risk. During power outages, people often resort to the use of kerosene space heaters, fire places, gas ranges, and even barbecues to heat homes. Do not use barbecues or gas ranges for a heat source. If unvented fuel burning space heaters are used for warmth, be sure that windows are opened slightly to provide fresh air into the living areas. Additionally, gas ranges should not be used without local exhaust, such as exhaust fans or vented hoods that are exhausted to the outside.

Combustion

Tobacco smoke, including second hand smoke, is a large source of CO in homes with smokers. Smokers have higher COHb values than nonsmokers and exposure to secondary tobacco smoke results in an increase in COHb values. Smokers generally have COHb values of five to six percent. Nonsmokers have COHb levels of 0.5 percent, whereas nonsmokers exposed to secondary tobacco smoke have been shown to have COHb levels in the two to three percent range.

Automobiles, Campers, RVs, and Boats

CO produced from cars left running in closed garages can accumulate and enter the home. Traveling in truck canopies and campers presents an especially high risk for children. The University of Washington and Virginia Mason have reported deaths and loss of consciousness and other signs of CO exposure in children in Washington State who were affected while riding in covered truck beds. CO will accumulate in this space because the shape of the truck produces turbulence, which can lower the air pressure in the truck bed, drawing exhaust into the covered area. No one should ride inside covered truck beds. Every year there are deaths associated with CO poisoning. The majority of these deaths are associated with motor vehicle exhaust (CO) leaking into cars, campers, and motor homes. **Be sure to provide adequate ventilation. It is important that cars and trucks have a functional "tight" exhaust system.**

Prevention

To prevent or reduce exposure to CO, be sure to provide ventilation during fuel burning appliance use, do not run cars in closed garages, and maintain your car's exhaust system. If your home has fuel burning appliances you may want to obtain a CO alarm. These units are very similar to smoke alarms and warn occupants when CO levels become unsafe. There are also several monitors available that change color during CO exposure. These are not very precise in indicating CO levels. The gas company will test your home for CO if you are a customer and suspect a gas leak, smell combustion fumes, or describe symptoms associated with CO exposure. There are also independent testing labs that can test your home; however, they do charge a fee. If you suspect a problem with a gas appliance, contact your gas supplier.

See the DOH Carbon Monoxide Web fact sheet for more information.

If you think you have a problem, act immediately: leave, call from outside the home, and do not return to the home until the problem has been

resolved. Severe CO poisoning symptoms require emergency medical treatment.

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Nitrogen Oxides

Nitrogen oxides are highly toxic and irritating gases with a pungent odor.

Sources

The primary source for indoor nitrous oxides are gas burning appliances.

Concentrations

Indoor nitrogen dioxide (NO_2) concentrations range between .03-.5 PPM with peak concentrations of .7 PPM having been measured in kitchens and other rooms of homes during conventional gas cooking and use of unvented gas appliances. EPA's standard for outdoor air is 0.05 PPM. Generally, indoor concentrations do not exceed these standards, except during and shortly after use of unvented gas appliances.

Health Effects

Inhalation of nitrogen dioxide can induce effects similar to CO. Nitrogen oxides react with the blood's hemoglobin, decreasing the blood's oxygen-carrying capabilities and increasing cardiovascular stress. Nitrogen oxides can also produce temporary and long-term damage to bronchial airway and other lung tissues. Several studies, although not conclusive, have shown that children living in homes with gas appliances have elevated rates of minor respiratory illness and reduced respiratory function.

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Respirable Suspended Particulates

Respirable suspended particulates (RSP) are particles, organic and inorganic, that are suspended in the air and are small enough to be inhaled into the lungs. RSPs are also often referred to as PM2.5 or as PM_{10}s, particulate matter 2.5 microns or 10 microns in size or less.

Sources

The major source is tobacco smoke. There is increasing evidence that wood smoke is also a major contributor during the heating season. Unvented gas appliances and kerosene heaters also produce RSP.

Concentrations

There are no indoor standards for RSP. EPA has, however, established an annual average outdoor standard of 15 ug/m3 (micrograms per cubic meter), and a maximum 24-hour standard of 65 ug/m3 for PM 2.5's. PM 10 standards

are set at 50 ug/m3 for an annual average outdoor, and a maximum 24 hour standard of 150 ug/m^3 for respirable particulates. As previously mentioned, these standards are often exceeded in indoor environments where smoking is permitted.

Health Effects

RSPs are comprised of many different compounds. Radon and benzo-a-pyrene, suspected carcinogenic agents, are transported by RSPs into the lungs. Gases or other substances may also be carried by RSPs into the lungs. Respiratory illness, especially chronic illnesses like bronchitis, emphysema, and asthma may be linked to, or aggravated by, exposure to RSPs.

Control Methods

Control approaches for these pollutants center on improving combustion efficiency of various household equipment such as gas ranges, kerosene heaters, wood stoves, or fireplaces, along with adequate ventilation and substitution.

RSPs, tobacco smoke, allergens and microorganisms are often considered similarly with respect to control methods (see sections on tobacco smoke and microorganisms and allergens).

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Formaldehyde

Formaldehyde (HCHO) is a colorless, flammable gas with a pungent suffocating odor. It is the most important aldehyde produced commercially, and is used in the preparation of urea-formaldehyde and phenol-formaldehyde resins. It is also produced during the combustion of organic materials and is a component of smoke.

Health Effects

Health effects associated with exposure to HCHO fall into several categories. These include: irritant effects, sensitization, and carcinogenicity. HCHO is intensely irritating to the mucous membranes, which includes the eyes and respiratory tract. Common symptoms from exposure to HCHO include: burning eyes, nose, and throat; headache; and nausea. HCHO has the potential to sensitize exposed individuals, which can involve both asthma symptoms and skin reactions. Some people exposed to HCHO will develop asthma symptoms. These symptoms include wheezing and chest congestion. Urticaria (a skin condition marked by intensely itching wheals usually caused by an allergic reaction) has been reported following inhalation of HCHO fumes. HCHO can be considered a sensitizing agent. Documentation of this effect has been seen in dialysis patients, as well as persons chronically exposed to low levels in mobile homes. HCHO has been designated as a probable human carcinogen, and has also been designated as a workplace carcinogen by the National Institute for Occupational Safety and Health (NIOSH).

U.S. Occupational Safety and Health Administration and Washington State Department of Labor and Industries workplace regulations call for exposures which do not exceed 0.75 PPM as an eight hour time weighted average (TWA), with a 0.5 PPM action level, and a 2 PPM short-term exposure limit for 15 minutes. NIOSH recommends a 0.016 PPM eight hour TWA and a 0.1 PPM 15 minute ceiling. The American Council of Governmental Industrial Hygienists recommend a ceiling of 0.3 PPM.

No residential standard exists in Washington State. The American Society of Heating, Refrigeration, and Air Conditioning Engineers recommends a maximum continuous indoor air concentration of 0.1 PPM. Other states and several foreign countries have guidelines or standards for residential indoor air exposures which range from 0.1 to 0.5 PPM.

The odor threshold ranges from 0.05 PPM to 1 PPM. At concentrations of 0.05 to 0.5 PPM HCHO produces a definable sensation of eye irritation. In occupational studies, reports of eye tearing, prickling, stinging, and burning are reported at levels from 0.13 to 2.7 PPM. Airway irritation has been reported as low as 0.1 PPM, but more commonly occurs in ranges of 1 to 11 PPM. Symptoms range from the feeling of a dry throat, tingling of the nose, to a sore throat. However, airway irritation (at concentrations of 5-30 PPM) is characterized by cough, chest tightness, and wheezing. Chronic industrial exposure to concentrations ranging from 0.5 to 8.9 PPM produce changes in the nasal and pharyngeal mucosa, and complaints of throat irritation, diminished sense of smell, and dryness of the throat. HCHO has been associated with both the development of asthma and the initiation of asthma attacks. High levels (50-100 PPM) have been associated with swelling of the lung and movement of fluid into the lung, as well as pneumonia. Exposures to levels greater than 100 PPM can be fatal.

Sources

The major sources in residential settings are building materials. These products may contain phenol, urea, thiourea, or melamine resins which contain HCHO. HCHO has also been used in the paper, photographic, and clothing industries. It is used in the finishing of all permanent press material, and can be found in the glues used in furniture construction, or carpet and vinyl attachments.

Urea-formaldehyde resin containing products are the most common HCHO source in the home. This formulation is approved for interior grade materials such as plywood, hardwood cabinetry, and wall paneling. Urea-formaldehyde resins release trapped free HCHO, as well as HCHO resulting from chemical degradation. Degradation of HCHO resins can occur when these materials become damp from exposure to high relative humidities, or if the HCHO materials are saturated with water during flooding, or when leaks occur. The release of HCHO occurs when the acid catalysts involved in the resin formulation are reactivated. Levels of out-gassing can also increase with increasing temperatures and relative humidity.

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Control Methods

The prevention of problems associated with exposure to HCHO are best treated by source control. The selection of HCHO free or low-emitting products such as exterior grade plywood which use phenol HCHO resins for indoor use is the ideal starting point.

Alternatives to source control include: filtration, sealants, and fumigation treatments. Filtration can be achieved using selected adsorbents. Sealants involve coating the materials in question with two or three coats of nitro-cellulose varnish, or water based polyurethane. Three coats of these materials can reduce out-gassing by as much as 90 percent. Professional carrier gas treatment with ammonia will also minimize HCHO out-gassing.

Testing for HCHO can be accomplished with passive monitors, real time active monitors, or colorimetric sorbent tubes. Passive monitors can be purchased through industrial hygiene suppliers or through independent contractors who manufacture their own monitors. For listings in your area, refer to your telephone book under analytical laboratories or environmental services.

For more information about formaldehyde, please see the DOH Formaldehyde Web site.

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Household Chemicals

Sources

Many consumer products emit gaseous or particulate contaminants during their use or in storage. Consumer products, such as cleaners, waxes, paints, adhesives, detergents, paint strippers, dry cleaning agents, deodorizers, pesticides, solvents, and many home craft products can be sources of both organic and inorganic contaminants. Aerosols, which are widely used to package products such as cleaners, waxes, pesticides, polishes, paints, and adhesives, can be particularly important because they dispense the contents in a form that makes them readily available for direct inhalation. Each use of these products can release substantial quantities of particulates, solvents, and propellant. Additional sources for indoor volatile chemicals include plastics, textiles, building materials, and carpets which may release small amounts over long periods of time.

Health Effects

The wide variety of chemicals used in consumer products and materials precludes a discussion of specific household chemicals and their potential adverse health effects. The health risks associated with long-term exposure to the low levels commonly experienced in the indoor environment has not been investigated adequately. Willful abuse of aerosols and careless use of solvents in enclosed spaces have resulted in acute and chronic disorders and even death.

Control Methods

The primary means of control have been substitution and increased ventilation. Increased awareness and concern by the public has resulted in manufacturers substituting less toxic chemicals in many consumer products and prompting them to make more products available in non-aerosol form. In addition, consumers are being more selective in the type of products they choose and how they are used.

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Microorganisms, Allergens and Mold

Sources

A large variety of biological material is present in the indoor environment. Sources include virtually everything indoors, but mainly people, animals, plants, and insects.

Health Effects

Many different organisms are known to cause infection and many more can produce allergic responses in man. The inhalation of biological aerosols from people and animals is the primary means of contracting respiratory infections, although air-cooling equipment, humidifiers, cool-mist vaporizers, and nebulizers can also incubate and distribute bacterial aerosols indoors and could be a source of infection.

According to the National Health Survey, respiratory illnesses are responsible for more than half of all acute conditions. Pollen, molds, dust mites, animal dander, algae, and insect parts are known allergens. The effect of these antigens in the asthmatic and allergic individual has been well-defined.

Control Methods

Many illnesses, including respiratory illnesses, appear to be transmitted primarily from person-to-person. Overcrowding, reduced ventilation, and increased use of untreated recirculated air have a potential to increase concentrations of microorganisms and allergens. There is limited data establishing a correlation between acute respiratory disease and ventilation rates. More common control methods for preventing transmission of illnesses include less crowded living conditions, isolation of infected individuals, and vaccination.

Temperature and humidity conditions are important for many microorganisms, allergens, and molds. Molds need available water to grow. Studies have shown a relationship between respiratory infections and low or high relative humidity. Studies have also shown that the survival or infectivity of microorganisms and allergic mite and fungal populations is directly dependent on relative humidity. These studies suggest that maintaining a relative humidity between 40 to 60 percent indoors would minimize adverse health effects from microorganisms and allergens by reducing their indoor populations. Many of the microorganisms and allergens are also dependent on suitable temperatures to survive.

For the sensitive individual with allergies, dust control methods (air-cleaning devices) are recommended to reduce the concentration of potential allergens in the home. However, it is important to realize the efficiency and effectiveness of these devices differ and that they should not be used without other environmental control methods. Recent reports have questioned the ability of these units to significantly reduce symptoms because allergens of most concern, such as animal allergens, mite fecal pellets, and pollens quickly settle to the floor and, therefore, are not removed by air cleaning. Some studies have indicated that air conditioning alone is as effective as specialized air cleaning devices. This is most likely related to the control of relative humidity and the resulting control of microbial, mite, and fungal populations.

The first step to controlling mold growth involves stopping all available water sources. Quick drying of wet materials is next and should be accomplished within 24 hours. The smell of mold and visible mold growth are indications of a problem and testing is not generally recommended. The last step is clean-up with a five percent bleach solution. Keep in mind that permeable objects like mattresses and furniture may not be cleanable. In this instance, disposal of the contaminated objects may be the only viable option

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Pesticides

Sources

Pesticides are chemical or biological substances used to destroy, prevent, or control insects, vegetation, rodents, and other pest organisms. A 1976-77 EPA survey revealed that over 90 percent of U.S. households used pesticides and that over 80 percent of the households used them indoors. Twelve of the most commonly used pesticides were insecticides. Some of the most widely used pesticides are the disinfectants (anti-microbials). The study showed that over 90 percent of households use disinfectants in either the liquid or aerosol forms.

Use of pesticides in dwellings may be by the occupant or building maintenance staff who purchase an "off-the-shelf" product, or by a commercial pest control applicator. On occasion, the source of pesticide indoors may result from drift of the chemical from an outside application through open windows and doors. In addition to the direct application of pesticide in to household air, there are other sources which continually emit vapors into the living space. For example, the intrusion of chemical vapors from insecticides through the floors and walls from application to the crawl space and foundation of the dwelling, evaporation of residues from crack and crevice treatments to the interior of the building, and vapors from moth repellents and room deodorizers. In many areas pre- or post-construction treatment for carpenter ants or termite protection is undertaken. Some of these pesticides may persist in the home environment for many months or years after application. Chlordane (an insecticide of choice for termite and carpenter ant control) has been found to persist for over 20 years after treatment. Pesticides

considered nonpersistent last much longer indoors, where they are protected from sunlight, water, and other factors which hasten their degradation.

Health Effects

The large variety of pesticides used in and around dwellings prohibits a discussion of specific symptoms and potential adverse health effects associated with each pesticide. The health risks associated with long-term inhalation exposure to low levels commonly experienced in the indoor environment has not been adequately investigated. In addition to pesticides themselves, approximately 1,200 inert ingredients are currently registered for use in pesticide formulations. These include solvents, propellants, emulsifiers, and adjuvants. Adequate toxicological data is available for only about one-third of these additives. The EPA has serious concerns about potential health effects associated with 120 of these additives. Proper interpretation of airborne pesticides values is very important. While there are occupational airborne pesticide permissible exposures levels (PEL), based on five 8-hour working days per week, these have limited value in the home situation. If residential values exceed the PEL, they would also be excessive for the home. However, if airborne pesticide values are below the PEL, for a given chemical, this does not mean they are safe for residential occupants. Full-time homemakers and small children may spend in excess of 21 hours per day inside the home, nearly three times the 8-hour shift. It has been recommended that a healthy adult living at home should not be exposed to more than one-fourth the work place PEL. In addition, an infant, elderly person, or someone who is ill may be more susceptible to the effects of small amounts.

Control Methods

Corrective measures other than general improvement of IAQ is usually not warranted. Additional preventive measures are expensive and their success rate in lowering air concentrations is questionable. There are several ways to minimize exposure to indoor airborne pesticide levels:

- Increase the circulation of clean air in the house. When weather permits, periodically open windows and doors, and use fans to mix the air. In crawl spaces, clear or add vents and install a fan to constantly vent crawlspace air to the outside.
- Seal areas that directly contact treated soil, using grout, caulk, or sealant. Fill cracks in basement, ground floors, and walls, and openings around pipes, drains, and sumps
- Install a system that supplies outside air to appliances like clothes dryers and furnaces that now draw air from inside the house. Appliances that use indoor air may actually help draw vapors from the soil into the house through walls, floors, and basements.
- Check the condition of ducts in the crawlspace of the basement. Use duct tape to seal openings and joints

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Additional Pesticide Assistance Information

Application of a pesticide by a commercial applicator or a private individual contrary to label instructions is termed a misapplication and is a violation of both state and federal regulations. Enforcement of pesticide regulations and investigation of pesticide misapplications are under the jurisdiction of the Washington State Department of Agriculture (WSDA). If you believe that a misapplication has been made and you wish to file a complaint, contact WSDA at 360-902-2040 in Olympia, or 509-576-3064 in Yakima.

If you have questions regarding health effects of pesticides, you can contact your local health department or the DOH Pesticide Illness Program at 1-877-485-7316. If you have symptoms which you believe are associated with a recent application, you should contact your physician or Washington Poison Center (1-800-222-1222) for advice.

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Radon

Radon gas is a chemically inert, odorless, colorless, and tasteless naturally-occurring radioactive element found in soils and rocks that make up the earth's crust. It comes from the normal decay of radium. Because it is a gas, it can easily move through soil and water and enter the atmosphere. Radon gas has a half-life approximating four days, after which it decays into four daughter products. These solid decay products are not inert and often attach themselves to airborne particulates which may then enter the lungs. These particles with attached radon daughters may become lodged in the lungs where the radon daughters undergo rapid decay, emitting radiation that damages lung tissue.

Sources

In the Northwest, the major source of radon gas in the home is the soil beneath and surrounding the residence. Common entry routes are through cracks in concrete slabs; cracks between poured concrete slabs; and blocks, pores and cracks in concrete blocks, slab footing joints, and mortar joints; loose fitting pipes; sump pits; and floor drains. Houses built on foundations with a ventilated crawl space should have few problems. Houses with basements and those built directly on or in the ground have a higher potential for problems.

Concentrations

Concentrations of radon and its daughter products are usually measured in pico-Curies per liter (pCi/l). The current action level (the level at which you should consider modifications) is 4 pCi/l. The Bonneville Power Administration, in cooperation with the WSU cooperative extension service and local utilities, has measured radon in thousands of homes in Washington State. To date, levels have ranged from less than 1 to 103 pCi/l. Most of the higher levels have been found in Northeastern Washington, due to the naturally occurring radium in the soil and rock. Western Washington does not appear to have significant radon levels, although exceptions have been found. Nationally, the average radon concentration is approximately 1 pCi/1. **The only way to know about your house is to test.**

Health Effects

Like other radioactive materials, radon can cause cancer. Much of the knowledge of the health significance of radon and its progeny is based on the analysis of the effects of high exposures on underground miners. Based on several studies and current knowledge, the National Academy of Sciences believe that radon and its progeny are harmful at all exposure levels, and increased lengths of exposure and higher doses will increase the risk of cancer. EPA has estimated that as many as 10 percent of lung cancer deaths in the U.S. may result from exposure to indoor radon.

Control Methods

Usually, radon reduction is fairly simple and inexpensive. Methods, in order of increased complexity and expense, are:

- Seal radon entry points with appropriate caulking material and cover sumps and drains.
- Improve basement or crawl space ventilation by increasing vent number, size, and/or using fans.
- Increase the air pressure in ground floor or basement area to reduce radon entry.
- Ventilate the area under the basement or slab (sub-slab depressurization) to reduce the amount of radon available to enter the home.

Additional information and brochures regarding radon, its prevalence, measurement, and control techniques can be obtained by calling 1-800-SOS-RADON.

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Tobacco Smoke

Indoor tobacco smoke is a major contributor to airborne contaminants in the home and other indoor environments. Over 4,000 chemical compounds, of which 40 are known or suspected carcinogens, have been identified in tobacco smoke. Some of the more important pollutants are carbon monoxide, acrolein, hydrogen cyanide, formaldehyde, nitrous oxides, pyrene, nicotine, cadmium, and numerous carcinogenic polycyclic aromatic hydrocarbons. Environmental tobacco smoke (ETS), or the smoke that comes directly from burning tobacco, has up to 50 times the concentration of some carcinogenic compounds as does mainstream or exhaled smoke, because of the lower combustion temperature. ETS contributes approximately 90 percent of the total products of combustion from a cigarette.

Tobacco smoke is also the major source of respirable suspended particulates (RSP). Wood smoke, unvented gas appliances, and kerosene heaters also contribute to indoor RSP concentrations. Studies have shown that particulate concentrations in public buildings and homes where smoking is permitted often exceed EPA's 24-hour outdoor air quality standard.

Health Effects

The health effects related to ETS exposure have only recently been investigated. The acute effects of involuntary smoking often depend on the individual being exposed. Principal acute effects can include: irritation of the eyes, nose and throat; coughing; headache; nausea; increased blood pressure; increased heart rate; and elevated carboxyhemoglobin levels. Passive smoking also affects several vulnerable subgroups of the population more than others. Many people with pre-existing health conditions, particularly those with asthma and other respiratory diseases, are often severely affected by exposure to ETS.

Many studies have shown adverse health effects to children of smokers. These studies have shown an association with increased respiratory illness and decreased pulmonary function. Infants and children under two years old seem particularly susceptible. Infants exposed to passive smoke also have triple the rate of sudden infant death syndrome compared to nonexposed infants. In children of smoking parents, other effects also reported include decreased attention and work capacity, increased developmental disability and respiratory problems, and decreased school attendance.

It has long been known that smoking increases the risks of lung, laryngeal, oral, esophageal, other organ cancers, and heart disease. The association between ETS exposure and cancer is clear Increasing evidence indicates a high risk of lung cancer and heart disease for persons exposed to ETS. Several studies of nonsmoking wives of smoking husbands have found a statistically significant association between passive smoke exposure at home and risk of lung cancer. A recent study has reported that nonsmoking wives of husbands who smoke have three times the risk of heart attack than nonsmoking women married to nonsmokers. ETS may very likely be the most harmful indoor air pollutant.

Control Methods

Only the prohibition of smoking assures a smoke-free environment. Other control methods generally consist of increasing ventilation, use of air cleaning devices, or the restriction of smoking. For air cleaning devices to be effective, they must be large enough to circulate large volumes of air. Air cleaners, such as electrostatic precipitators, are only partially effective in that they remove only particulates and not the gases associated with tobacco combustion.

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Monitoring for Indoor Air Pollutants

Tools for monitoring and measuring indoor air pollutants are in a state of rapid evolution. Our capabilities to measure minute quantities of chemicals have evolved faster than our ability to identify the health implications associated with low levels commonly identified in the indoor environment. Currently, there are no recognized validated standard methods or procedures for monitoring and analyzing residential and nonoccupational indoor air. Generally, methods have either been research or standard methods that were developed for

other uses, usually occupational. Increasing concern and demand has resulted in rapid development and marketing of devices for measuring residential indoor air pollutants, particularly formaldehyde and radon.

The most common methods used to measure indoor air pollutants are use of an air pump to actively move air through a media to collect the pollutant of concern; or, a passive method that collects the pollutant by diffusion or permeation to absorbent media. Other methods are laboratory analyses of bulk samples for asbestos and radon monitoring devices.

Active monitoring systems are used by laboratories and environmental services. These methods are generally considered to more accurately measure pollutant concentrations. These services can be located by looking under **Laboratories-Analytical**, in the Yellow Pages of the telephone book. The costs for these services vary from company-to-company and depend on the type of service required.

Passive monitors for chemical pollutants are available from several different sources such as analytical laboratories, environmental services, safety and supply companies, and the manufacturer. Recent developments in passive monitors for formaldehyde have improved their accuracy and reliability. Passive monitors are considered an inexpensive alternate to active monitoring methods, and are routinely recommended for residential screening.

Monitoring devices and/or methods for common measurable pollutants follow:

Formaldehyde

- Active monitoring–consult with private analytical laboratory or environmental service.
- Passive monitors–available from environmental services and some safety and supply companies. Monitors are placed in the home and then returned for analysis. Prices vary.

Radon

- Radon-measuring devices are lightweight plastic monitors that vary in size from the size of a wristwatch to a tuna fish can. They are installed in the home and then returned to a laboratory for analysis. Sampling times vary from one month to one year.

Asbestos

- Asbestos cannot be identified by unaided visual inspection. However, it may be identified by chemical or microscopic methods. Bulk samples for asbestos analyses should be submitted to an analytical laboratory with asbestos analysis capabilities.
- These laboratories are listed in the Yellow Pages of the telephone book under **Laboratories-Analytical**.

Nitrous Oxides

- Passive monitors are also available for nitrous oxides. These monitors have been developed for industrial environment monitoring and usually are not sensitive enough to measure low levels found in the home. They may be useful for confirming higher levels of these pollutants. The monitors are available through safety and supply companies and some analytical laboratories.

Pesticides

- Measurement of airborne pesticide levels basically consists of three elements: 1) collection of the sample; 2) chemical analysis of the sample; 3) interpretation of the values found.
- Measurement of airborne pesticide levels in a home is not something that the average homeowner can do for himself. In most cases, it takes expensive equipment which must be precisely calibrated. A person must rely on private consulting and analytical laboratories.
- Measurement and analysis of samples is by no means inexpensive. Unless you have a recommendation from someone, the best way to locate a firm is by looking in the Yellow Pages of the telephone book under **Laboratories-Analytical**.

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Interpreting Results

Interpretation of results is often very difficult because of the wide susceptibility of individuals. In many instances where indoor air related illnesses have been suspected, a wide range of different pollutants have been identified with no one pollutant identifiable as a causative agent. In many instances, it may be a combination of two or more pollutants that produce the adverse health effects. Remember, there are no universally accepted IAQ standards for the residential and non-occupational environment. Lastly, it must be realized that a host of variables can influence single readings and values may not necessarily reflect average values. Local health agencies can often be of assistance in interpreting results.

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Need More Information?

Please contact:

- Local Health Department
- US Environmental Protection Agency, IAQ Publications/Resources 1-800-438-4318
- Washington State Department of Ecology, Local Air Pollution Control Agencies 1-360-407-6000
- Washington State Department of Labor & Industries, Health and Safety Consultation (non-residential problems) 1-800-547-8367

Should you need additional information, please contact one of the following DOH Staff:

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- Paul Marchant, (360) 236-3363, paul.marchant@doh.wa.gov